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# United States Patent
**Sprinkle**

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(54) **APPARATUS AND METHOD FOR SPEAKER TUNING AND AUTOMATIC DIGITAL SIGNAL PROCESSING CONFIGURATION**


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***H04R 1/02*** (2006.01)
(Continued)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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See application file for complete search history.



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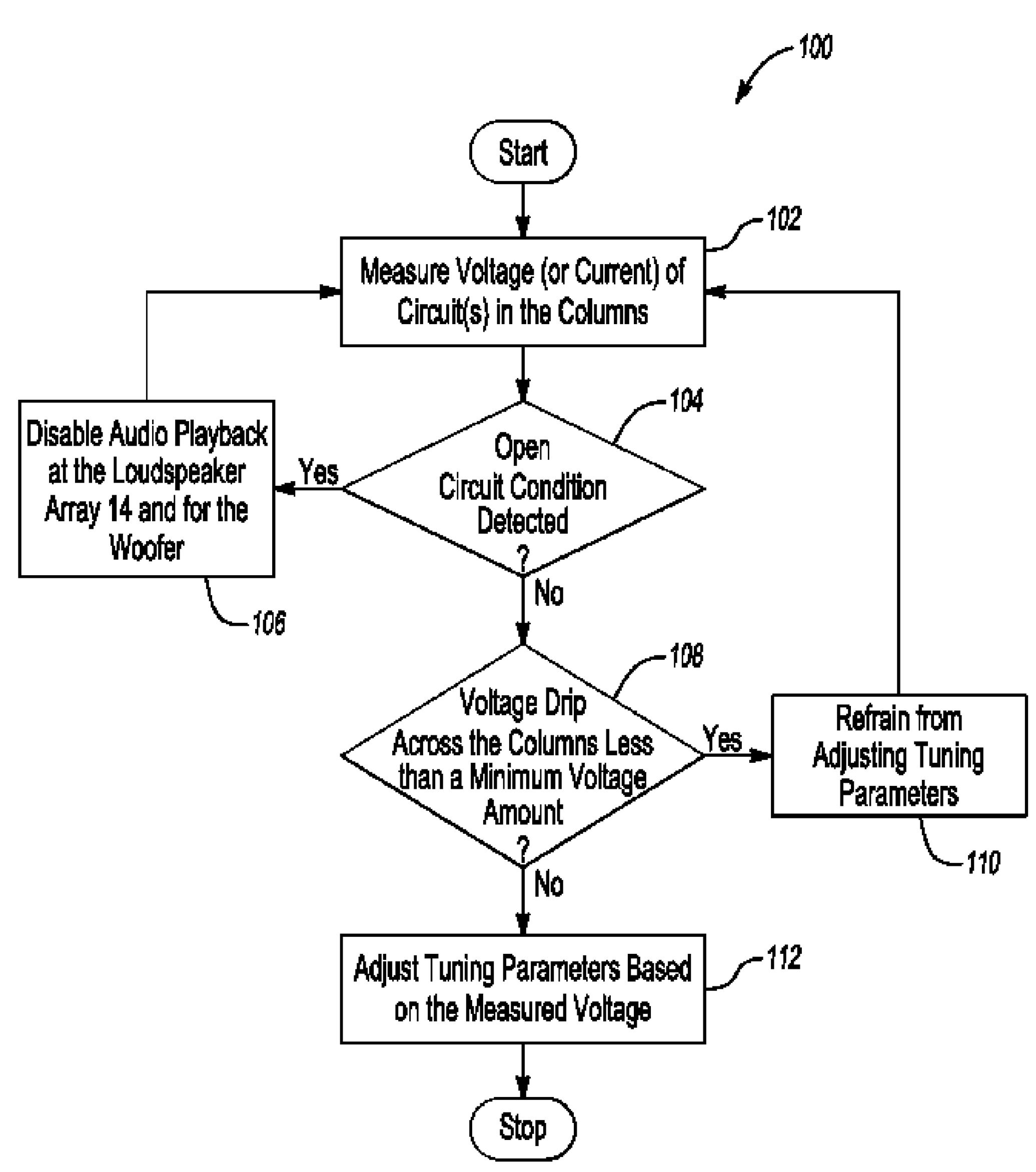
(57) **ABSTRACT**

A loudspeaker system including a loudspeaker array, an audio controller, and one or more insertable columns are provided. The loudspeaker array is configured to playback an audio output in a listening environment. The audio controller is configured to provide the audio output to the loudspeaker array. The one or more insertable columns is positioned between the audio controller and the loudspeaker to adjust a height of the loudspeaker array relative to the audio controller.


**20 Claims, 4 Drawing Sheets**



(51) **Int. Cl.**

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|---|---|
| ***H04R 1/40*** | (2006.01) |
| ***H04R 3/12*** | (2006.01) |
| ***H04R 1/26*** | (2006.01) |

(52) **U.S. Cl.**
CPC ......... ***H04R 3/12*** (2013.01); *H04R 2201/401* (2013.01)

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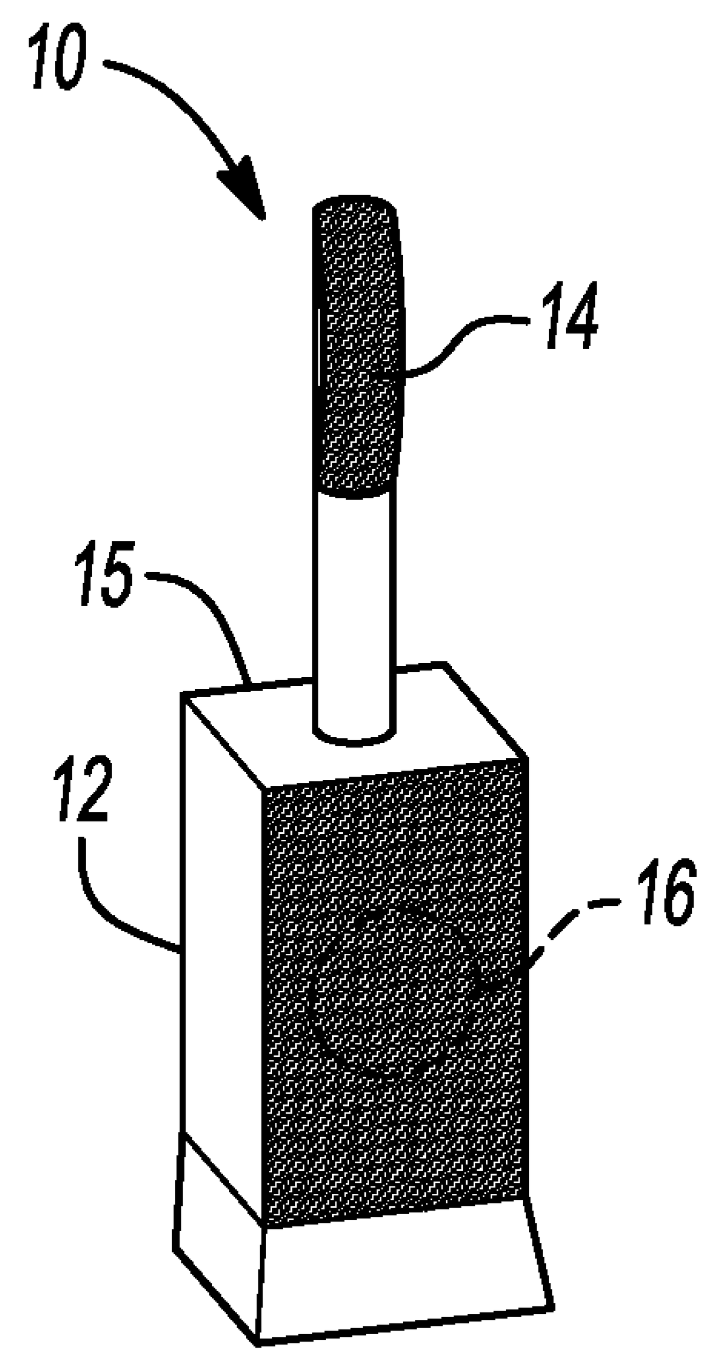


Fig-1

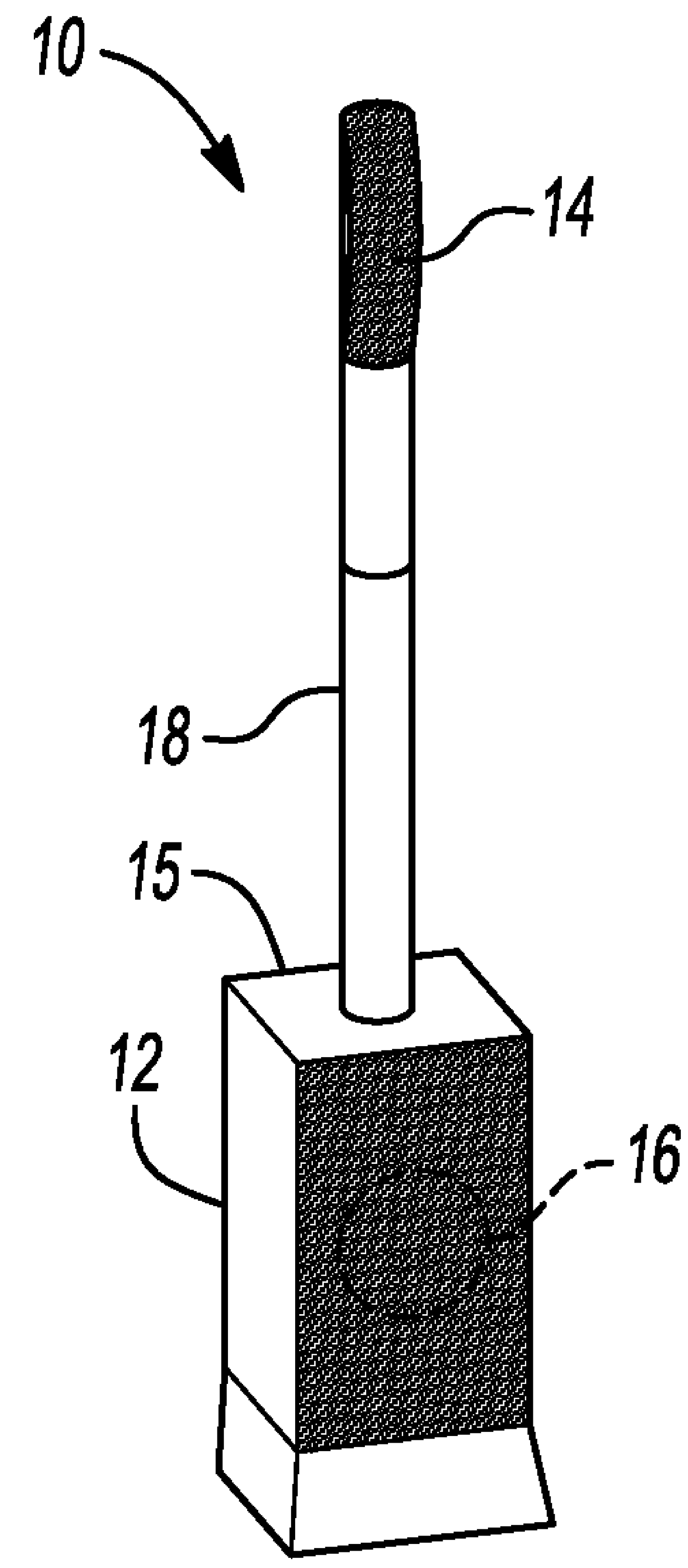


Fig-2

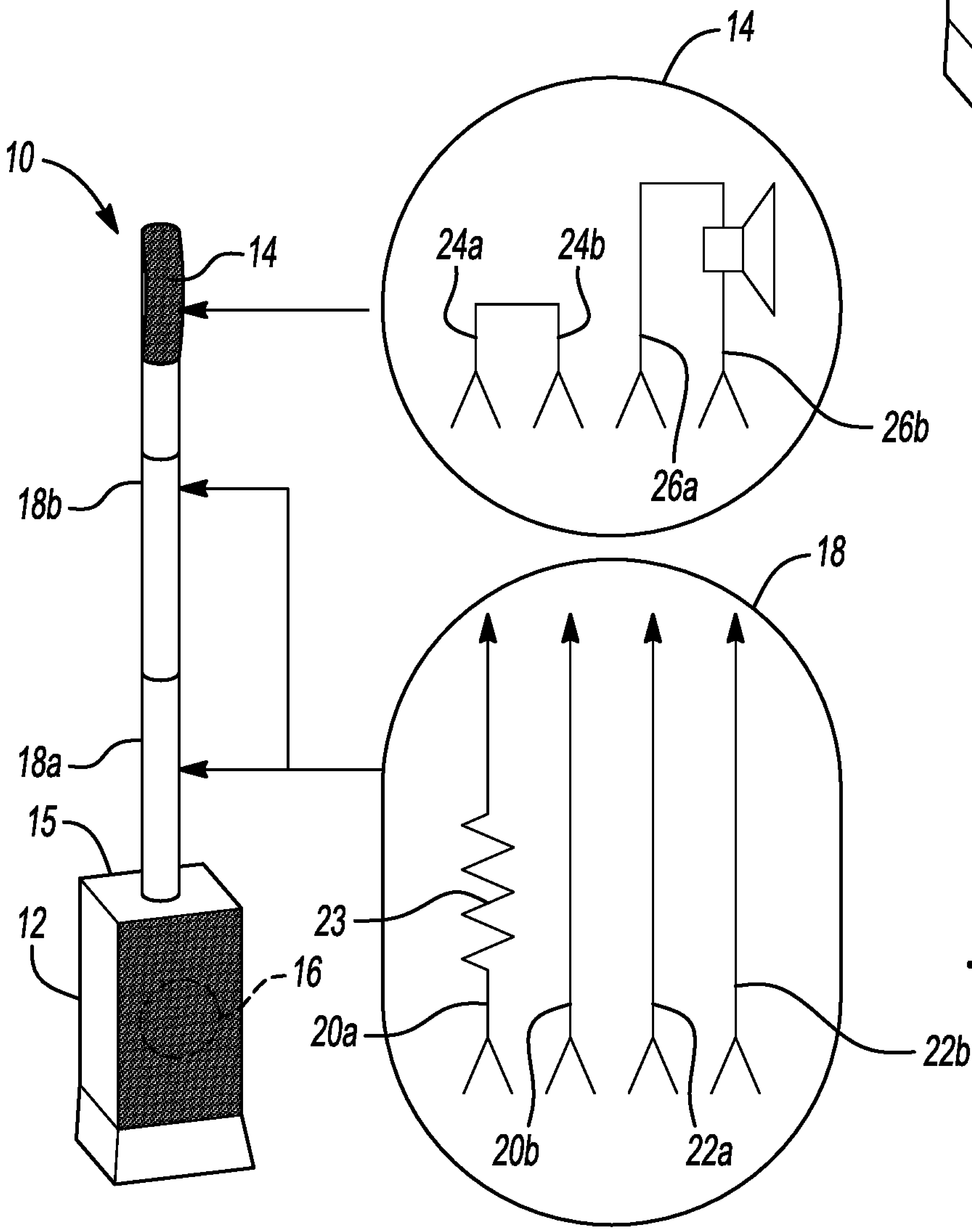


Fig-3

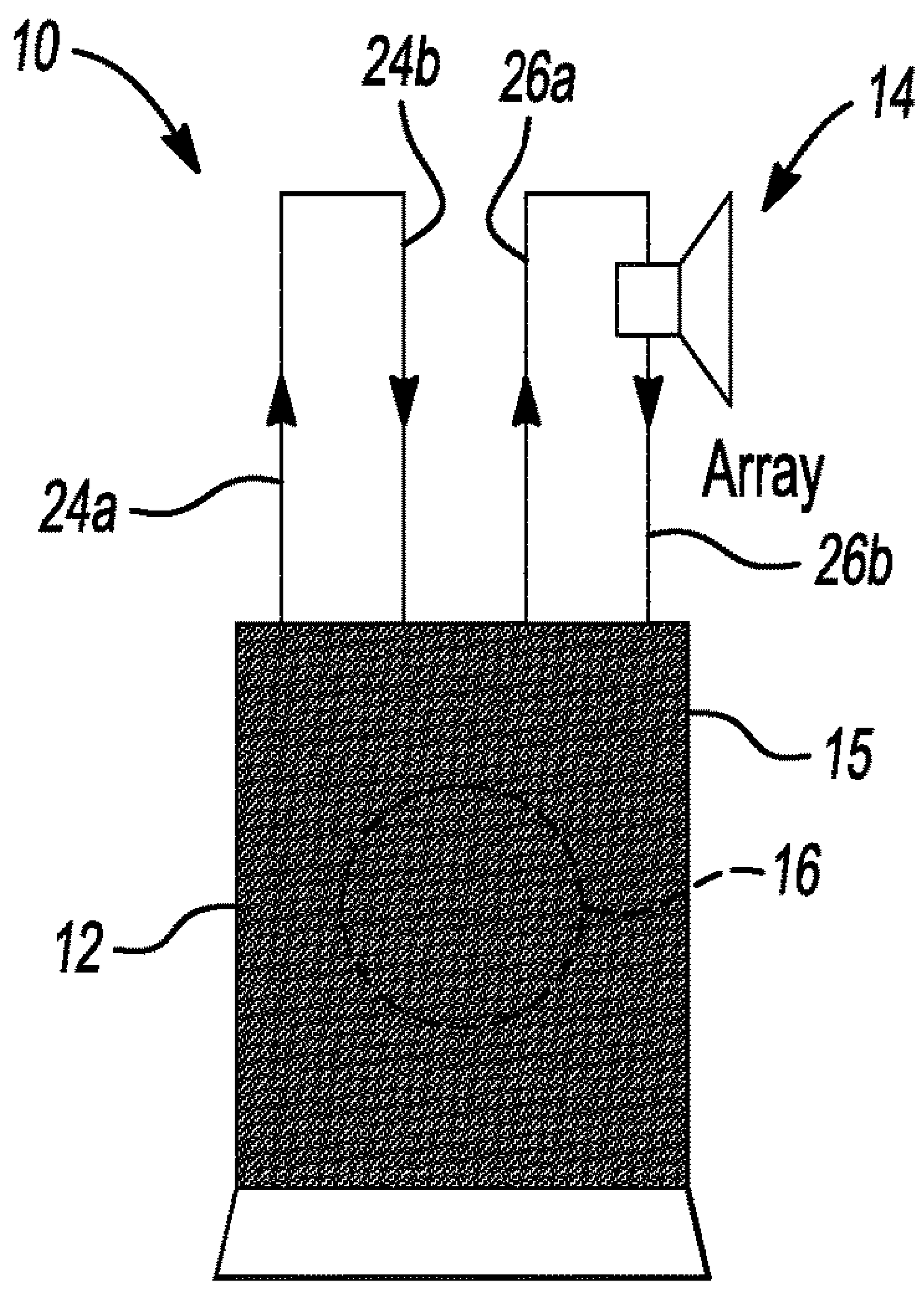


Fig-4

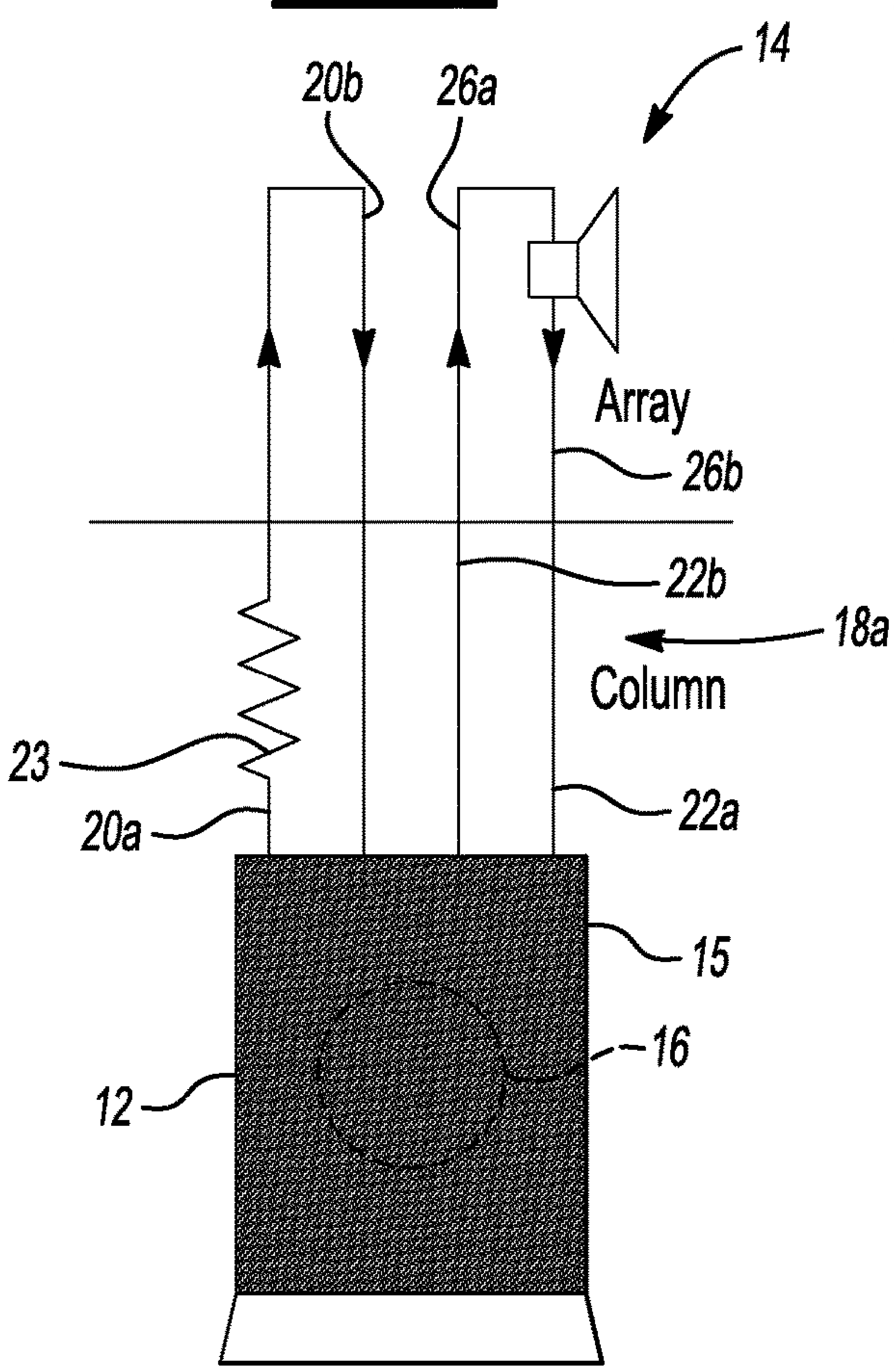


Fig-5

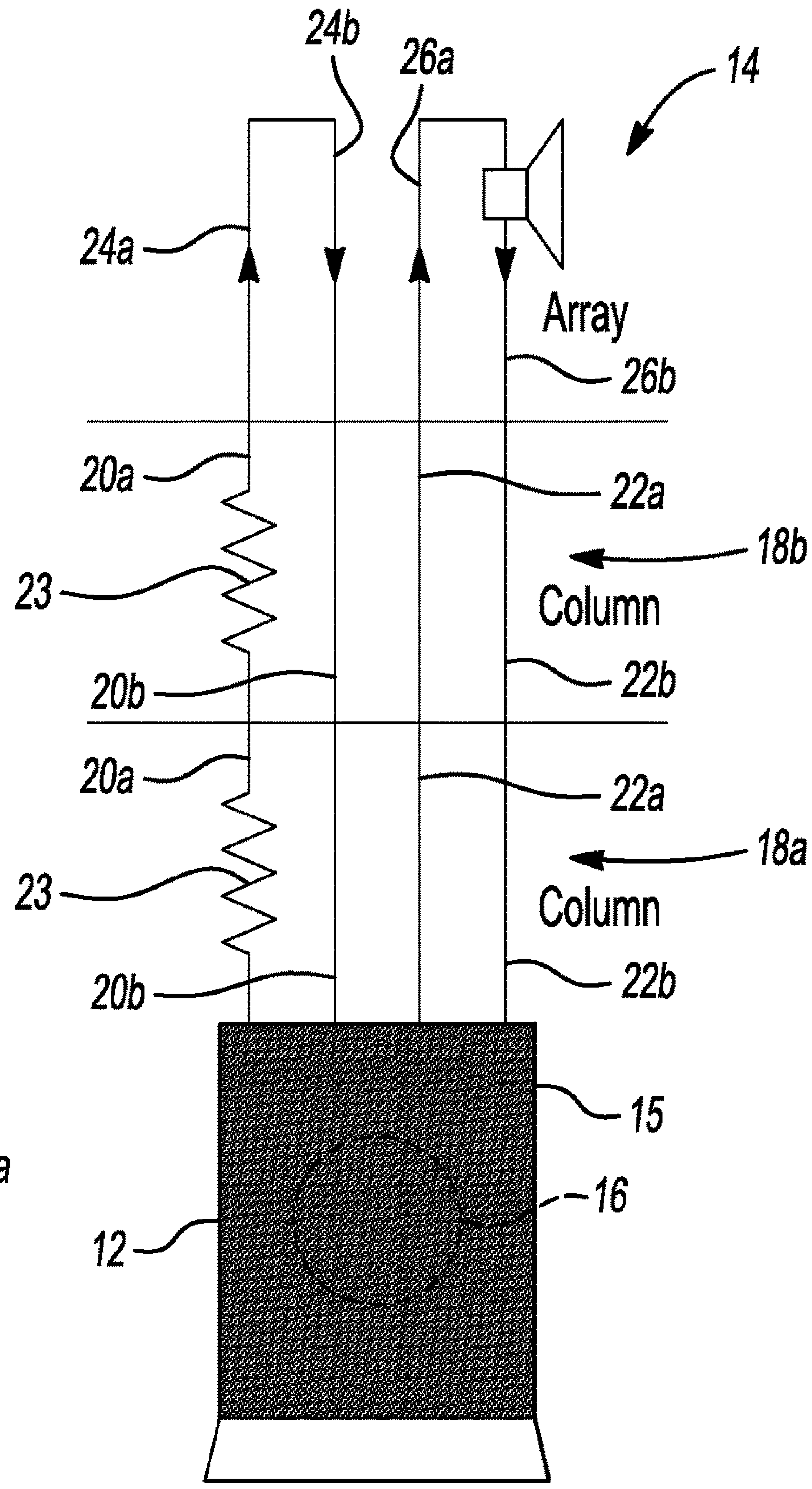


Fig-6

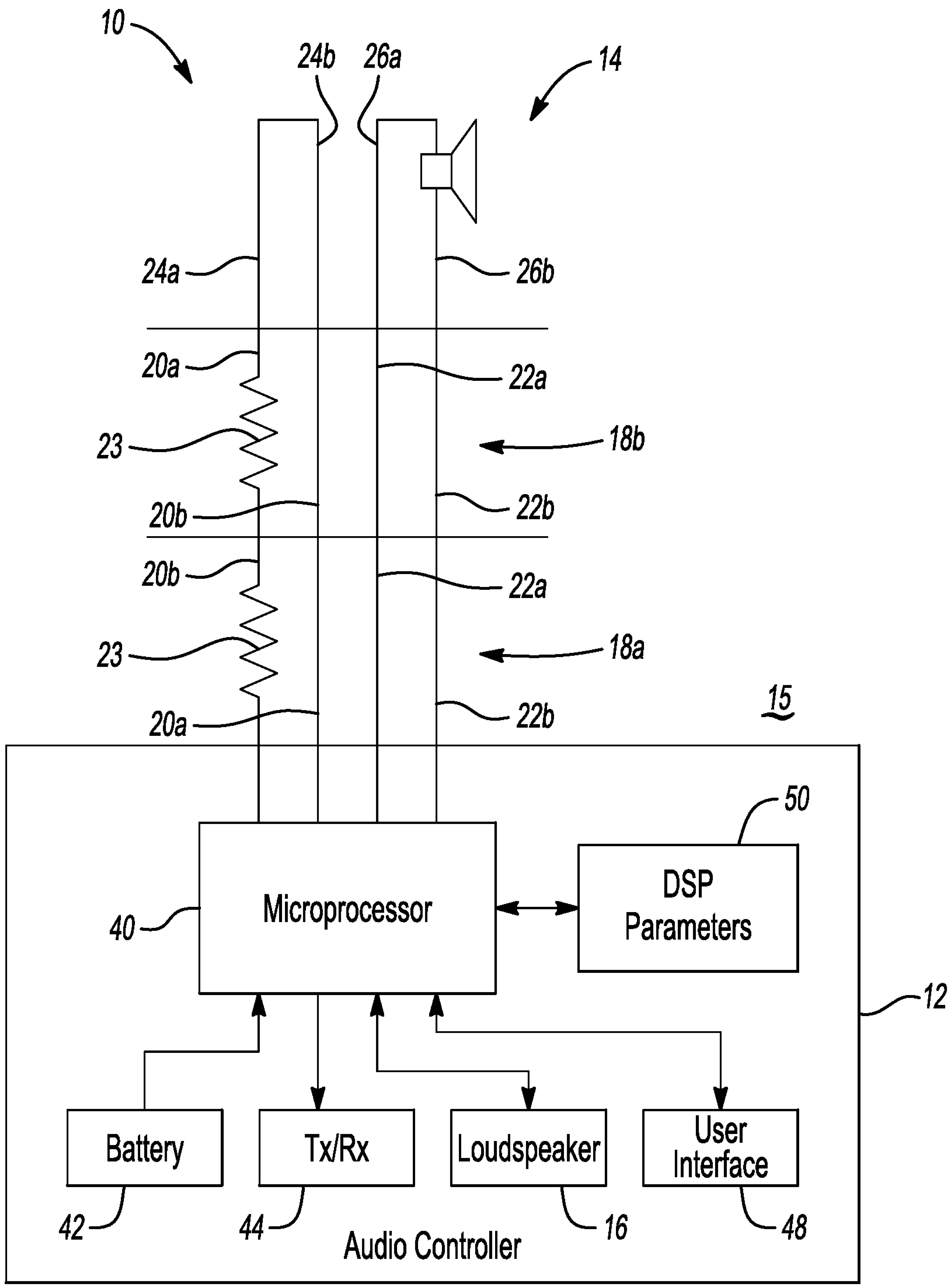
10
24b
26a
14
24a
26b
20a
22a
23
18b
20b
22b
20b
22a
23
18a
20a
22b
15
50
Microprocessor
DSP
Parameters
40
12
Battery
Tx/Rx
Loudspeaker
User
Interface
42
44
16
48
Audio Controller

Fig-7

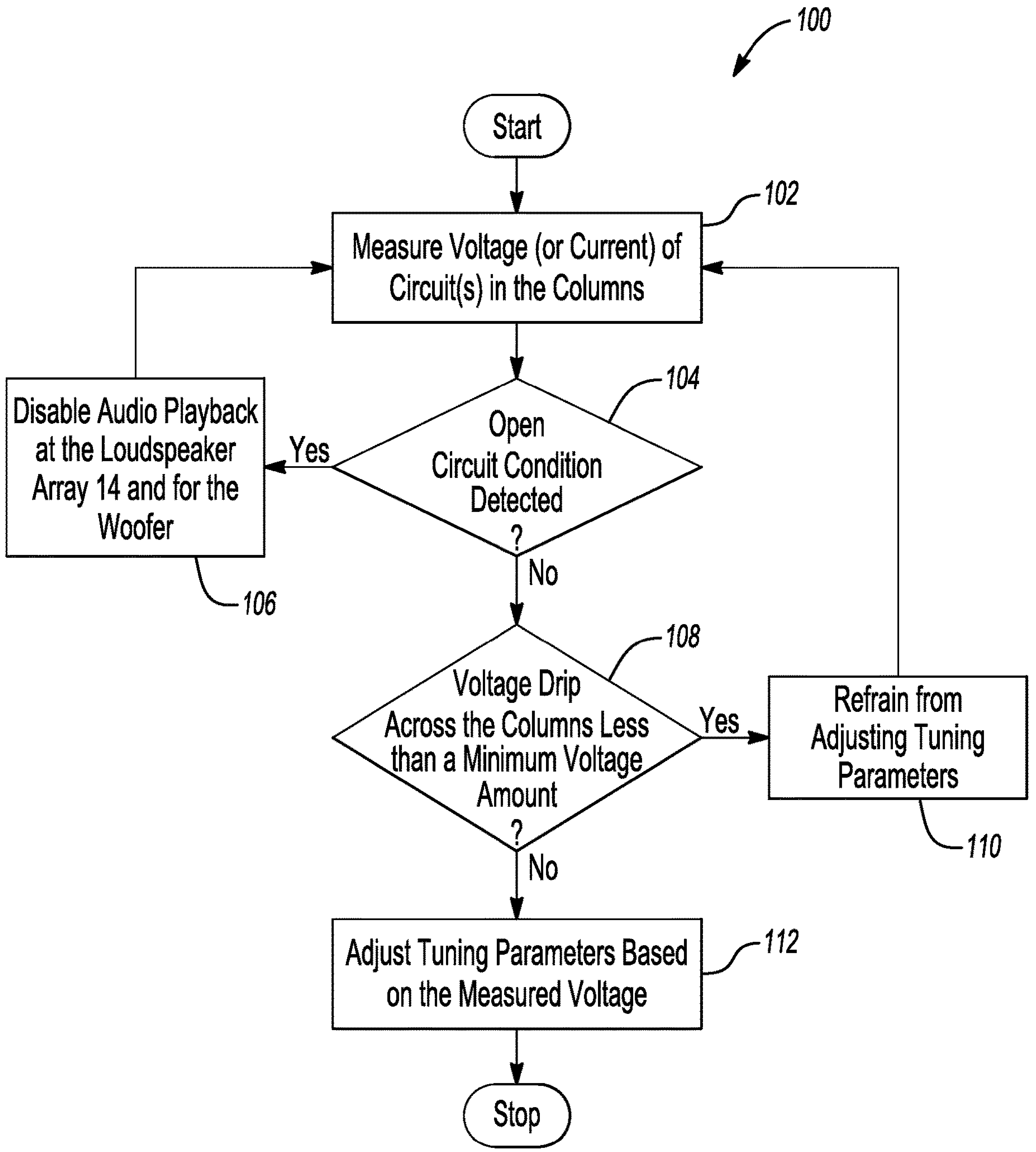
100
Start
102
Measure Voltage (or Current) of Circuit(s) in the Columns
104
Open Circuit Condition Detected ?
Yes
Disable Audio Playback at the Loudspeaker Array 14 and for the Woofer
106
No
108
Voltage Drip Across the Columns Less than a Minimum Voltage Amount ?
Yes
Refrain from Adjusting Tuning Parameters
110
No
Adjust Tuning Parameters Based on the Measured Voltage
112
Stop

Fig-8

# APPARATUS AND METHOD FOR SPEAKER TUNING AND AUTOMATIC DIGITAL SIGNAL PROCESSING CONFIGURATION

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is the U.S. National Phase of PCT Application No. PCT/US2018/035683 filed Jun. 1, 2018, which claims the benefit of U.S. provisional application Ser. No. 62/513,866 filed Jun. 1, 2017, the disclosures of which are incorporated herein by reference.

## TECHNICAL FIELD

Aspects disclosed herein generally relate to a system and method for speaker tuning and automatic digital signal processing (DSP) configuration.

## BACKGROUND

U.S. Pat. No. 9,615,163 to Nachman et al. discloses a loudspeaker port that may include tunable physical components to tune the port to different frequencies to improve speaker efficiency at those frequencies. The ports may be activated by at least partly opening associated shutters, or disabled by closing the associated shutters. Activated ports may enhance speaker efficiency in a frequency range. However, activated ports may also introduce sound artifacts, thereby reducing sound quality. Therefore, the ports may be disabled when appropriate to reduce their negative impact to sound quality. A Digital Signal Processor (DSP) may determine the frequency components of a played sound to determine when to open the ports and how to tune the ports. Accordingly, a loudspeaker may benefit from the improved efficiency facilitated by the ports while also avoiding typical drawbacks created by the ports.

## SUMMARY

In at least one embodiment, a loudspeaker system is provided. The loudspeaker system includes a loudspeaker array, an audio controller, and one or more insertable columns. The loudspeaker array is configured to playback an audio output in a listening environment. The audio controller is configured to provide the audio output to the loudspeaker array. The one or more insertable columns is positioned between the audio controller and the loudspeaker to adjust a height of the loudspeaker array relative to the audio controller.

In at least another embodiment, a loudspeaker system is provided. The loudspeaker system includes a loudspeaker array, an audio controller, and one or more insertable columns. The loudspeaker array is configured to playback an audio output in a listening environment. The audio controller is configured to provide the audio output to the loudspeaker array. The one or more insertable columns are positioned between the audio controller and the loudspeaker array to adjust a height of the loudspeaker array relative to the audio controller based on a size of the listening environment.

In at least one embodiment, a loudspeaker system is provided. The loudspeaker system includes a loudspeaker array, one or more insertable columns, and an audio controller. The loudspeaker array is configured to playback an audio output in a listening environment. The one or more insertable columns is electrically connected to the loudspeaker array. The audio controller is configured to provide the audio output to the loudspeaker array via the one or more insertable columns.



## BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the present disclosure are pointed out with particularity in the appended claims. However, other features of the various embodiments will become more apparent and will be best understood by referring to the following detailed description in conjunction with the accompanying drawings in which:

FIG. **1** generally depicts a speaker system for automatic DSP adjustment based on a first length in accordance to one embodiment;

FIG. **2** generally depicts the speaker system for automatic DSP adjustment based on a second length in accordance to one embodiment;

FIG. **3** generally depicts the speaker system for automatic DSP adjustment based on a third length in accordance to one embodiment;

FIG. **4** generally depicts a more detailed implementation of the speaker system for automatic DSP adjustment based on the first length in accordance to one embodiment;

FIG. **5** generally depicts a more detailed implementation of the speaker system for automatic DSP adjustment based on the second length in accordance to one embodiment;

FIG. **6** generally depicts a more detailed implementation of the speaker system for automatic DSP adjustment based on the third length in accordance to one embodiment;

FIG. **7** generally depicts a more detailed implementation of the speaker system in accordance to one embodiment; and

FIG. **8** generally depicts a method for automatic DSP adjustment in accordance to one embodiment.

## DETAILED DESCRIPTION

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

The embodiments of the present disclosure generally provide for a plurality of circuits or other electrical devices. All references to the circuits and other electrical devices and the functionality provided by each are not intended to be limited to encompassing only what is illustrated and described herein. While particular labels may be assigned to the various circuits or other electrical devices disclosed, such labels are not intended to limit the scope of operation for the circuits and other electrical devices. Such circuits and other electrical devices may be combined with each other and/or separated in any manner based on the particular type of electrical implementation that is desired. It is recognized that any circuit or other electrical device disclosed herein may include any number of microcontrollers, a graphics processor unit (GPU), integrated circuits, memory devices (e.g., FLASH, random access memory (RAM), read only memory (ROM), electrically programmable read only memory (EPROM), electrically erasable programmable read only memory (EEPROM), or other suitable variants thereof) and software which co-act with one another to perform operation(s) disclosed herein. In addition, any one or more of the electrical devices may be configured to execute a computer-program that is embodied in a non-transitory computer readable medium programmed to perform any number of the functions as disclosed.

Aspects disclosed herein provide a speaker system including an audio controller that detects a voltage and/or other mechanical switch that indicates a physical configuration of at least one loudspeaker and adjusts digital signal processing (DSP) tuning parameters automatically based on the voltage or the output of the mechanical switch. The speaker system includes an audio controller that provides an audio input signal to the at least one loudspeaker for audio playback. One or more insertable columns may be positioned between the audio controller and the at least one loudspeaker to adjust a distance (or height) between the audio controller and the at least one loudspeaker based on a desired audio output from the at least loudspeaker. In one example, each column may include any number of resistors and various wires to connect to a connector of the at least one loudspeaker. The audio controller measures the voltage across the resistor(s) and also determines whether the at least one loudspeaker is connected to wires of the system. The audio controller adjusts tuning parameters of the at least one loudspeaker based on the number of resistors that are connected (i.e., based on the measured voltage which varies based on the height of the at least one loudspeaker in reference to the audio controller). The number of resistors implemented in the speaker system is based on the overall height of the at least one loudspeaker to the audio controller. As the height increases, the number of resistors increase and the overall resistance increases. Conversely, as the height decreases, the number of resistors that are connected to the audio controller decrease and the overall resistance decreases. In addition, the audio controller mutes the at least one loudspeaker and a bass woofer from playing back the audio input signal if the at least one loudspeaker is disconnected from the audio controller.

FIG. **1** generally depicts a speaker system **10** for automatic DSP adjustment based on a first length in accordance to one embodiment. The system **10** generally includes an audio controller **12** and a loudspeaker array **14**. The number of loudspeakers implemented in the array **14** may vary based on the desired criteria of a particular implementation. The audio controller **12** is generally configured to transmit an audio input signal to the loudspeaker array **14**. The loudspeaker array **14** plays back the audio input signal for a user. The loudspeaker array **14** may playback the audio input signal at any frequency over 300 Hz. For example, the loudspeaker array **14** may include any number of tweeters and/or mid-range speakers to playback the audio input signal for the noted frequencies.

The audio controller **12** includes at least one loudspeaker **16** that may be any number of woofers and play back the audio input signal at frequencies less than 300 Hz. A loudspeaker enclosure **15** includes the audio controller **12** and the at least one loudspeaker **16**. The overall height between the audio controller **12** and the loudspeaker array **14** as illustrated in FIG. **1** may correspond to a default height in which it is not necessary for the audio controller **12** to adjust various DSP related tuning parameters for the loudspeaker array **14**. However, the system **10** enables a user to adjust the height (or distance) between the audio controller **12** and the loudspeaker array **14** to accommodate playing back the audio input signal in a larger room or venue. As shown in FIG. **1**, the user increases the height between the loudspeaker array **14** and the loudspeaker enclosure **15**. In addition, the user may desire to adjust the height to accommodate for audience location/seating. To this end, FIG. **2** depicts the speaker system **10** in which the user can increase the height between the audio controller **12** and the loudspeaker array **14** by adding one or more insertable columns (or spacers) **18**. For example, the user may insert the column(s) **18** between the audio controller **12** and loudspeaker array **14**. The user also has the option of removing the column(s) **18** as desired to return the speaker system **10** to its default position for audio playback. The speaker system **10**, as illustrated in FIG. **2**, provides a single column **18** between the audio controller **12** and the loudspeaker array **14**.

FIG. **3** generally depicts the speaker system **10** in which columns **18*a*** and **18*b*** (i.e., multiple columns) are inserted between the audio controller **12** and the loudspeaker array **14**. As shown, the addition of the columns **18*a*** and **18*b*** increase the height between the audio controller **12** and the loudspeaker array **14** (or the loudspeaker enclosure **15**). It is generally recognized that as the height between the audio controller **12** and the loudspeaker array **14** changes, tuning parameters may need to be changed to ensure that the loudspeaker array **14** properly plays back the audio input signal accordingly in conjunction with the loudspeaker **16**. The audio controller **12** includes a digital signal processor (not shown) that includes various tuning parameters that can be altered based on the overall height of the loudspeaker array **14**. Each column **18** generally includes a first pair of wires **20*a*-20*b*** and a second pair of wires **22*a*-22*b***. The first wire **20*a*** includes at least one resistor **23**. It is recognized that any number of resistor(s) **23** may be implemented in a single column **18**. The loudspeaker array **14** generally includes a third pair of wires **24*a*-24*b*** and a fourth pair of wires **26*a*-26*b***. The audio controller **12** is electrically connected to the first, second, third, and fourth pairs of wires **20*a*-20*b***, **22*a*-22*b***, **24*a*-24*b***, and **26*a*-26*b***, respectively. Each column **18** may be coupled to one another or to the loudspeaker array **14** via a snap and lock arrangement or via interference fit with ends thereof (i.e., ends of the column **18**).

In general, the first pair of wires **20*a*-20*b*** is electrically connected to the third pair of wires **24*a*-24*b***, respectively, and the second pair of wires **22*a*-22*b*** is electrically connected to the fourth pair of wires **26*a*-26*b***, respectively. As shown, the third pair of wires **24*a*-24*b*** form a circuit with the first pair of wires **20*a*-20*b*** and the audio controller **12**. Likewise, the fourth pair of wires **26*a*-26*b*** form a circuit with the second pair of wires **22*a*-22*b***. In operation, the audio controller **12** measures the voltage across the resistor(s) **23** and adjusts various DSP tuning related parameters to account for the height of the loudspeaker array **14**. As expected, the measured voltage corresponds to the resistance values of the resistor(s) **23** and on an overall resistance of the wires **20*a***, **20*b***, **22*a***, **22*b***, **24*a***, **24*b***, etc. themselves. The overall resistance of the wires **20*a***, **20*b***, **22*a***, **22*b***, **24*a***, **24*b*** may be attributed the type and/or gauge of the wire in addition to the overall height (or length) of these wires with respect to the audio controller **12** (or portion of the enclosure **15** in which the audio controller **12** is positioned). Each column **18** may include electrical connectors (not shown) for coupling the various wires **20*a***, **20*b***, **22*a***, **22*b***, **24*a***, **24*b***, etc. For example, the audio controller **12** may control parameters such as but not limited to a delay, EQ, parametric parameters, etc. based on the measured voltage (or current) (or measured electrical output) (e.g., the height of the loudspeaker array **14**). With the increase in height and the adjustment of tuning parameters, the system **10** avoids source separation where the user perceives sound coming from different locales. Instead, the loudspeaker array **14** plays back the audio input signal seamlessly with the loudspeaker **16** and this may hold true for any height. For example, when the loudspeaker array **14** is in its lowest position, the user does not get the impression that the loudspeaker array **14** and the loudspeaker **16** are competing with one another such as a smearing sound. Rather, there is a nice and smooth blend of the audio between the loudspeaker array **14** and the loudspeaker **16**.

Thus, depending on the number of columns **18** inserted between the audio controller **12** and the loudspeaker array **14**, the measured voltage across the resistors **24** vary accordingly and the audio controller **12** adjusts the tuning parameters of the loudspeaker array **14** based on measured voltage. This condition is based on the overall height of the loudspeaker array **14**. Likewise, when the loudspeaker array **14** is electrically disconnected from the audio controller **12** (e.g., the wires **26***a*-**26***b* are disconnected from either the second pair of wires **22***a*-**22***b* or from input pins (not shown) of the audio controller **12**), the audio controller **12** detects an open circuit condition and ceases to transmit the audio input signal (e.g., mutes the loudspeaker array **14**). The audio controller **12** also disables transmitting the audio input signal to the loudspeaker **16** (or to the woofer(s)) when an open circuit condition is detected.

FIG. **4** is a more detailed view of the system **10** illustrated in FIG. **1**. In this case, the system **10** is in a default position whereby no columns **18** are inserted between the audio controller **12** and the loudspeaker array **14**. FIG. **5** is a more detailed view of the system **10** illustrated in FIG. **2**. In this case, a single column **18** (e.g. a single resistor **23**) is inserted between the audio controller **12** and the loudspeaker array **14**. The insertion of the single column **18** between the audio controller **12** and the loudspeaker array **14** correspond to a first predetermined height and the audio controller **12** adjusts the tuning parameters for the loudspeaker array **14** to playback the audio input signal based on the first predetermined height (or measured voltage across the resistor **23**).

FIG. **6** is a more detailed view of the system illustrated in FIG. **3**. In this case, two columns **18***a* and **18***b* (e.g., multiple resistors **23** are provided in series) are inserted between the audio controller **12** and the loudspeaker array **14**. The insertion of the two columns **18***a* and **18***b* between the audio controller **12** and the loudspeaker array **14** correspond to a second predetermined height and the audio controller **12** adjusts the tuning parameters for the loudspeaker array **14** to playback the audio input signal based on the second predetermined height (or measured voltage across the resistors **23**). As noted above, when the loudspeaker array **14** is removed from the system **10**, the audio controller **12** detects an open circuit condition and ceases to transmit or provide the audio input signal until the loudspeaker array **14** is electrically coupled back to the audio controller **12**. The audio controller **12** also disables transmitting the audio input signal to the loudspeaker **16** (or to the woofer(s)) when an open circuit condition is detected.

FIG. **7** depicts a more detailed view of the audio controller **12**. The audio controller **12** includes a microprocessor **40**, a rechargeable battery **42**, a transceiver **44**, the loudspeaker **16** (or woofer), a user interface **48** and DSP tuning parameters **50**. As shown, the microprocessor **40** is electrically connected to the various columns **18***a* and **18***b* (i.e., resistors **23**) and to the loudspeaker array **14**. The microprocessor **40** generally includes a voltage measurement circuit (not shown) to measure the voltage across the resistor(s) **23**. Likewise, the voltage measurement circuit may also detect the open circuit condition in the event the loudspeaker array **14** is removed from the system **10**.

The transceiver **44** enables the audio controller **12** to wirelessly receive the audio input signal from another audio source (not shown). In one example, the audio controller **12** may wirelessly communicate with the other audio source via Bluetooth, WiFi or other suitable wireless interface. It is recognized that the audio controller **12** may also wirelessly transmit the audio input signal to another playback device such as a mobile device, headphone, tablet, etc. The user interface **48** includes various switches (not shown) to enable the user to adjust volume, select various channels, bass control, reverb control, treble control, etc. While not shown, the audio controller **12** may also include a USB port for charging and/or receiving the audio input signal for playback. It is recognized that the audio controller **12** may include any number of channels for mixing different audio signals.

FIG. **8** generally depicts a method **100** for automatic DSP adjustment in accordance to one embodiment. In operation **102**, the audio controller **12** measures the voltage (or current) across the various pairs of wires **20***a*-**20***b*, **22***a*-**22***b*, **24***a*-**24***b*, and/or **26***a*-**26***b*. In the event the column(s) **18** are not attached to the loudspeaker array **14**, the audio controller **12** may measure the voltage (or current) across wires **24***a*-**24***b* and **26***a*-**26***b*. In operation **104**, the audio controller **12** determines whether an open circuit condition is present. If the audio controller **12** determines that an open circuit condition is present, then the method **100** moves to operation **106**. If not, then the method **100** moves to operation **108**.

In operation **106**, the audio controller **12** disables the transmission of the audio input signal to the loudspeaker array **14** and to the loudspeaker **16** (e.g., mutes the audio playback). n operation **108**, the audio controller **12** determines whether a voltage drop across the wires **20***a*-**20***b* and **24***a*-**24***b* is less than a predetermined minimum voltage amount. If the audio controller **12** determines that the voltage drop is less than the predetermined minimum voltage amount, then the method **100** moves to operation **110**. In this case, the height of the loudspeaker array **14** has not moved and is in the default position (i.e., none of the columns are coupled to the audio controller **12**). If not, then the method **100** moves to operation **112**. In operation **110**, the audio controller **12** refrains from adjusting any tuning parameters for the loudspeaker array **14** as there is no change in the height of the loudspeaker array **14**. In operation **112**, the audio controller **12** adjusts tuning parameters based on measured voltage which correspond to a height of the loudspeaker array **14**.

While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the invention.

What is claimed is:

**1**. A loudspeaker system comprising:

a loudspeaker array configured to playback an audio output in a listening environment;

an audio controller configured to provide the audio output to the loudspeaker array; and one or more insertable columns being positioned between the audio controller and the loudspeaker to adjust a height of the loudspeaker array relative to the audio controller,

wherein the audio controller is further configured to adjust tuning parameters of the audio output based on the height.

**2**. The system of claim **1**, wherein each insertable column includes at least one resistor.

**3**. The system of claim **2**, wherein the audio controller is further configured to measure an electrical output across the at least one resistor for each insertable column.

**4**. The system of claim **3**, wherein the audio controller is further configured to adjust the tuning parameters associated with the loudspeaker array based on the measured electrical output.

**5**. The system of claim **4**, wherein the tuning parameters correspond to a delay, equalization, and parametric parameters.

**6**. The system of claim **1**, further comprising at least one loudspeaker that is separated from the loudspeaker array by the one or more insertable columns.

**7**. The system of claim **6**, wherein the at least one loudspeaker is a woofer and wherein the loudspeaker array includes at least one of any number of tweeters and any number of mid-range speakers.

**8**. The system of claim **6**, wherein the audio controller is further configured to disable transmitting the audio output to the at least one loudspeaker in response to detecting that the loudspeaker array is electrically disconnected from the audio controller.

**9**. The system of claim **1**, wherein the one or more insertable columns enable electrical communication between the audio controller and the loudspeaker array.

**10**. A loudspeaker system comprising:

a loudspeaker array configured to playback an audio output in a listening environment;

an audio controller configured to provide the audio output to the loudspeaker array; and

one or more insertable columns being positioned between the audio controller and the loudspeaker array to adjust a height of the loudspeaker array relative to the audio controller based on a size of the listening environment,

wherein the audio controller is further configured to adjust tuning parameters of the audio output based on the height.

**11**. The system of claim **10**, wherein each insertable column includes at least one resistor.

**12**. The system of claim **11**, wherein the audio controller is further configured to measure an electrical output across the at least one resistor for each insertable column.

**13**. The system of claim **12**, wherein the audio controller is further configured to adjust the tuning parameters associated with the loudspeaker array based on the measured electrical output.

**14**. The system of claim **13**, wherein the tuning parameters correspond to a delay, equalization, and parametric parameters.

**15**. A loudspeaker system comprising:

a loudspeaker array configured to playback an audio output in a listening environment;

one or more insertable columns being electrically connected to the loudspeaker array; and

an audio controller configured to provide the audio output to the loudspeaker array via the one or more insertable columns,

wherein the one or more insertable columns adjust a height of the loudspeaker system; and

wherein the audio controller is further configured to adjust tuning parameters of the audio output based on the height.

**16**. The system of claim **15**, wherein the one or more insertable columns increases an overall height of the loudspeaker array relative to a loudspeaker enclosure including at least one loudspeaker.

**17**. The system of claim **15**, wherein each insertable column includes at least one resistor.

**18**. The system of claim **17**, wherein the audio controller is further configured to measure an electrical output across the at least one resistor for each insertable column.

**19**. The system of claim **18**, wherein the audio controller is further configured to adjust the tuning parameters associated with the loudspeaker array based on the measured electrical output.

**20**. The system of claim **19**, wherein the tuning parameters correspond to a delay, equalization, and parametric parameters.

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